COMMUNICATING RISK TO THE PUBLIC

FIRST, LEARN WHAT PEOPLE KNOW AND BELIEVE

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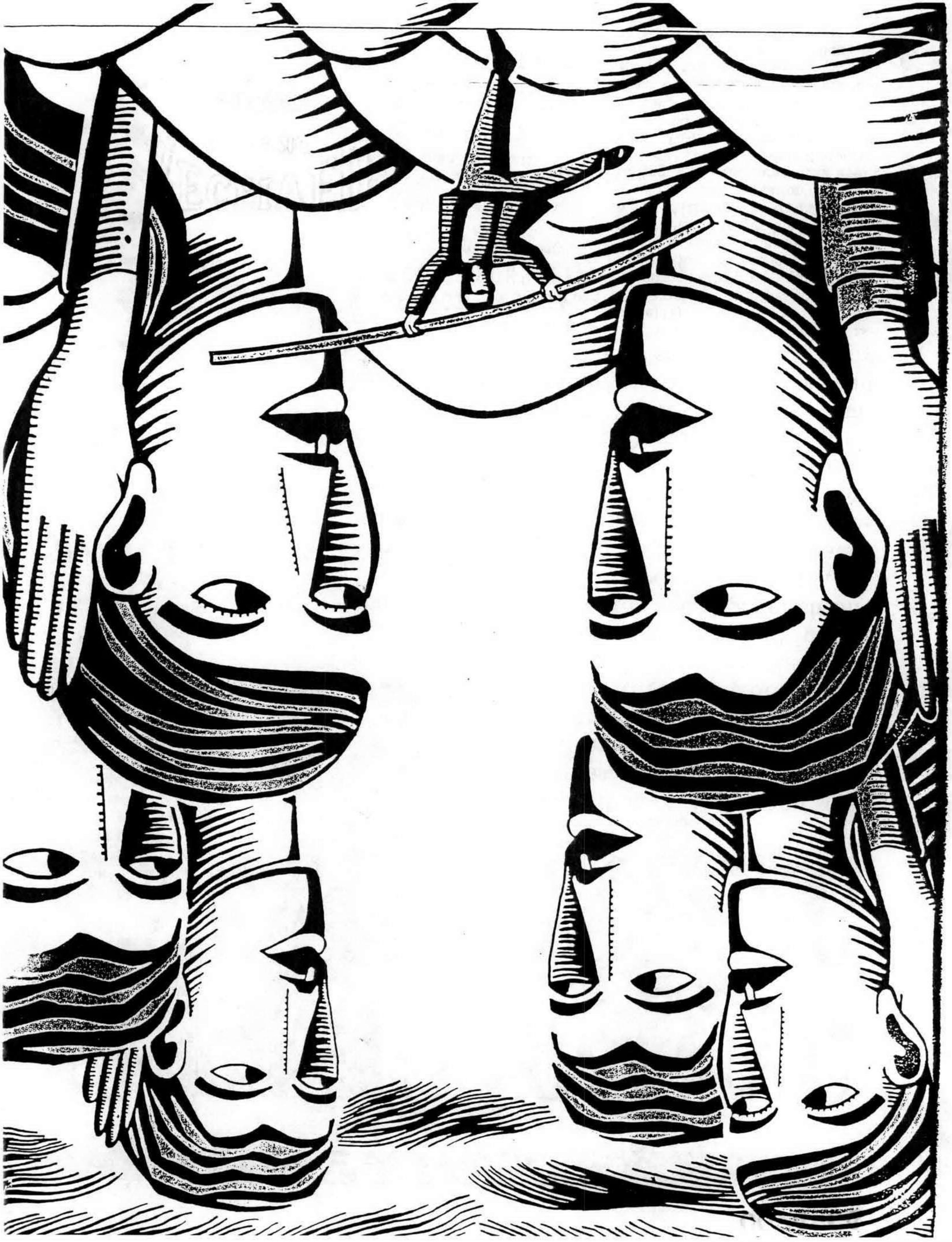
As the recognition of risks in our society increases, so does the volume of communications about those risks. Recent examples include the Chemical Manufacturers Association's Community Awareness and Emergency Response program, which has been widely applied in programs to communicate to the neighbors of chemical plants, and the U.S. Surgeon General's AIDS brochure, sent to all residents of the United States. Such efforts add to the flow of risk communications concerning environmental pollutants (e.g., chemical plant fact sheets), drugs and medical devices (package inserts, informed consent briefings), natural disasters (radio warnings, pamphlets), nutrition (food labels, health classes), and occupational health and safety (material safety data sheets, posters in the workplace) (*1*).

The stated aim of these communications is to supply people with the information they need to make informed decisions about risks to their health, safety, and environment. Although everyone agrees that "risk communication" involves telling someone something about risk, often that is the extent of agreement. To many of the manufacturers or managers of technologies that create risks, "risk communication" means persuading the public that the risk from a technology is small and should be ignored. In such contexts, Sheila Jasanoff (*2*) has suggested that "risk communication is



often a code [word] for brainwashing by experts or industry." Clearly, there are ethical considerations in risk communication (*3–7*).

Within the community of risk professionals the phrase has come to mean communication that supplies lay people with the information they need to make informed independent judgments about risks to health, safety, and the environment (*3–10*). Lay people make personal decisions about their exposures to risks, such as those associated with radon and diet, over which they exercise considerable individual control. Lay people also participate in democratic government processes by which decisions are made about risk issues, such as building a nuclear power plant, over which individuals can exercise relatively little control. To quote Thomas Jefferson about these processes, "diffusion of knowledge among the people" is the only sure strategy "for the preservation of freedom and happiness."

The research reported here seeks to present people with information they need in a form that fits their intuitive ways of thinking. It is intended to support the social and political processes of managing risks in a democratic society. If risks were better understood, some conflicts would be avoided. Other risks that have received too little scrutiny might become the focus of informed debate (*3–7, 11*).

If lay people were trained decision analysts, then it would be straightforward to determine what information they need. A decision analysis would be constructed for the decisions that they face, their current knowledge would be assessed, and the additional information they need to help them distinguish among the available options could be calculated. For example, homeowners deciding whether to test for radon would need to know the likelihood that their house has a high radon level, the health risk of various radon levels, the cost and accuracy of testing procedures, and the cost and efficacy of possible remediation measures (*8–10*).

However, people sometimes do not need to know much in order to make an informed decision. For example, the probability of having a radon problem might be small enough or the cost of remediation large enough that individuals would gain nothing by testing.

The information they will require mum content for communications directed at lay people. Remarkably few communications include any numbers at all regarding the magnitude of risks or the confidence that can be placed in risk estimates. In their stead are recommendations such as "practice safe sex" or "if your measured radon level is above the standard, hire an approved contractor." The implicit assumption of these communications is that people will let others do the decision analysis for them, trusting some expert to apply the best scientific evidence toward identifying the course of action in their best interests. That trust could, however, be strained whenever the expert has a vested interest in which actions are taken, has values different from the client's, or disagrees with other experts.

Even when trust is complete, however, numbers alone may not suffice. Especially when they refer to very small quantities or are expressed in unfamiliar units, the numbers simply may not "speak" to people. To get an intuitive feeling for the nature and magnitude of a risk, people may need some understanding of the physical processes that create and regulate it. Moreover, independent knowledge of the substance of an issue provides one basis for evaluating experts' pronouncements.

Substantive information may be even more important in pre- and post-decision activities. Long before they make any decisions, people may be monitoring public discussion of a hazard, trying to establish some competence in the issues, and formulating options for future action. After an option has been chosen, implementing it (or making midcourse corrections) can require further knowledge of how things work.

Analogous issues arise when control over hazards is exercised through political processes. Lay people must decide whether to support or oppose a technology, as well as how to express those beliefs. A substantive understanding of risk processes may be important for evaluating the competence of those responsible for a hazard.

A "mental models" approach

People process new information within the context of their existing beliefs. If they know *nothing* about a topic, then a new message will be incomprehensible. If they have erroneous beliefs, then they may misconstrue the message. For example, even science students who get good grades will graft new knowledge onto fundamentally incorrect naive "mental models" for a long time, before replacing them with technically correct models (*12–16*). Such mental models play significant roles in how people acquire new skills, operate equipment, and follow instructions (*17–23*). As a result, communicators need to know the nature and extent of a recipient's knowledge and beliefs if they are to design messages that will not be dismissed, misinterpreted, or allowed to coexist with misconceptions (see box "Four steps for risk communication.")

The influence diagram

As an organizing device, we construct an expert *influence diagram*, a directed network showing the relationships among the factors relevant to a hazard-related decision (*25*). Figure 1 shows a representative portion of such a diagram for managing the risk of radon in a house's crawl space. This diagram was developed iteratively with a group of experts who reviewed successive drafts. In it, knowledge about exposure and effects processes is represented hierarchically; the higher levels are more general. An arrow indicates that the value of the variable at its head depends on the value of the variable at its tail. Although they can be mapped into decision trees, influence diagrams are more convenient for displaying the functional relationships among variables.

No lay person would have this mental model. However, it provides a template for characterizing a layperson's mental model. That characterization can be performed in terms of the *appropriateness* of people's beliefs, their *specificity* (i.e., level of detail), and *category of knowledge*. We distinguished among five categories: exposure processes, effects processes (i.e., health and physiology), mitigation behaviors, evaluative beliefs (e.g., radon is bad), and background information (e.g., radon is a gas). In evaluating appropriateness, we characterized beliefs as accurate, erroneous, peripheral (correct, but not relevant), or indiscriminate (too imprecise to be evaluated).

Open-ended procedure

Elicitation. In the design of our interview protocol, a primary objective was to minimize the extent to

Four steps for risk communication

1. Open-ended elicitation of people's beliefs about a hazard, allowing expression of both accurate and inaccurate concepts.
2. Structured questionnaires designed to determine the prevalence of these beliefs.
3. Development of communications based on what people need to know to make informed decisions (as determined by decision analysis) and a psychological assessment of their current beliefs.
4. Iterative testing of successive versions of those communications using open-ended, closed-form, and problem-solving instruments, administered before, during, and after the receipt of messages.

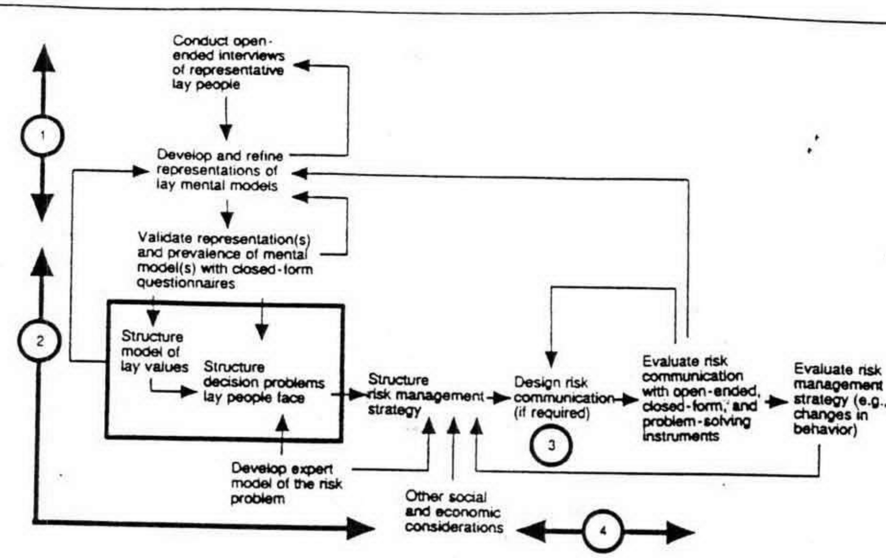
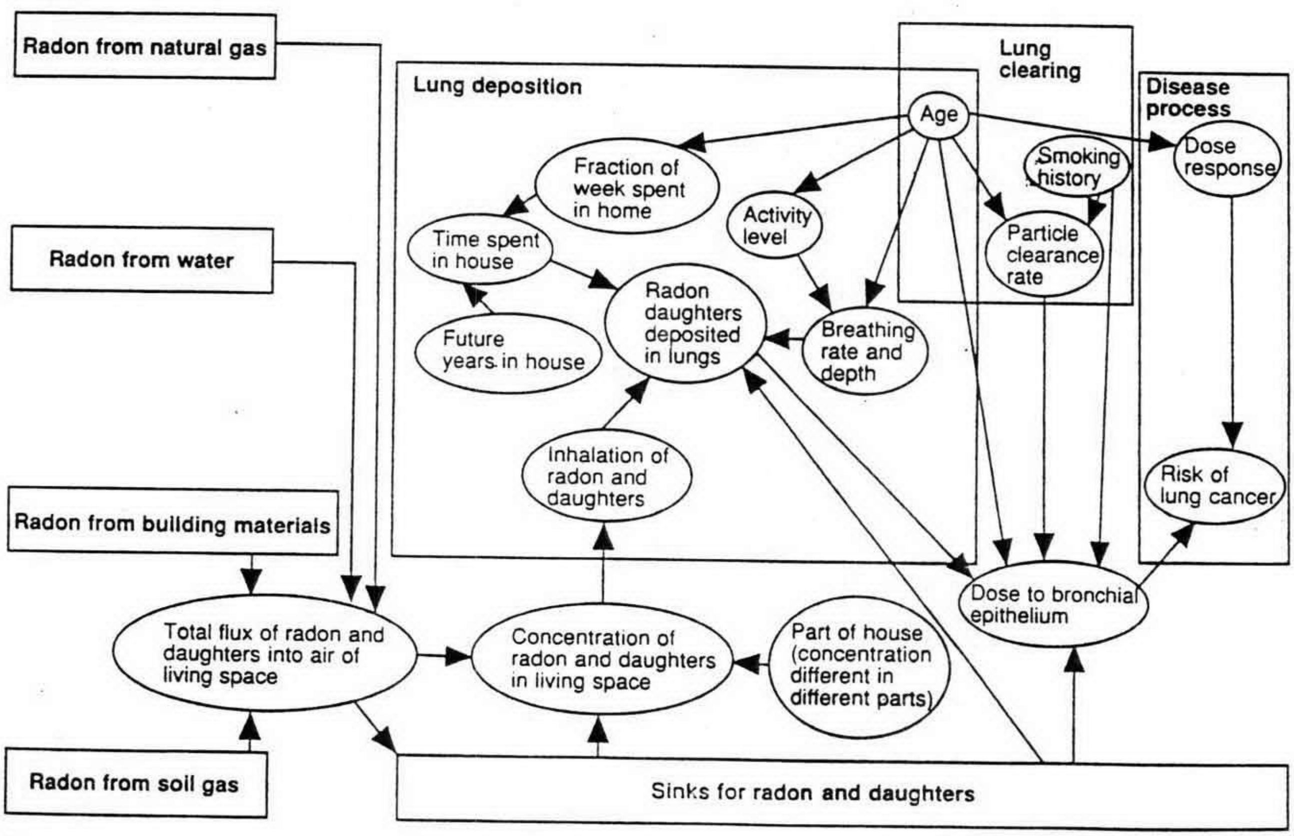


Illustration of how the four-step approach to risk communication, based on people's mental models of risk processes (*24*), fits within the broader process of risk management.

FIGURE 1

Expert influence diagram for health effects of radon[a]



[a] In a home with a crawlspace; this diagram was used as a standard and as an organizing device to characterize the content of lay mental models.

which the investigator's perspective is imposed on the respondent. Instead of asking directed questions, we began with an open-ended approach: "Tell me about radon." To ensure that respondents had ample opportunities to address all aspects of the influence diagram, we provided increasingly directed prompts. Specifically, we asked respondents to elaborate on each comment that they had made in the "tell me about" stage. Then, we encouraged them to describe exposure, effects, risk-assessment, and risk-management processes. These basic categories seemed so essential that mentioning them would correct an oversight rather than introduce a foreign concept.

A part of our protocol for radon is

presented (see box "Radon interview protocol"). The protocol was followed assiduously. Interview transcripts were reviewed periodically to insure that they conformed to the protocol. These controls were needed to prevent the interviewer from helping respondents with their answers. A single trained interviewer conducted all the interviews reported here.

In the final stage of the interview, respondents were asked to describe what each of several dozen photographs showed and to explain why it was either relevant or irrelevant to radon. The session began with two examples whose status seemed obvious (a photo of EPA's radon brochure and a photo of Mickey Mouse). The other photographs covered a wide range of topics. In general, beliefs evoked by this task should be less central to respondents' thought processes than those produced spontaneously. When previously unmentioned beliefs appear here, they are likely to represent latent portions of people's mental models—the sort that might emerge in everyday life if they had cause to consider specific features of their own radon situation. For example, when shown a supermarket produce counter, some respondents told us that these plants might have become contaminated by taking up radon from the soil in which they grew. In cases in which photos evoked erroneous beliefs, respondents likely had labile mental models to begin with.

Representation. Once elicited, beliefs must be represented in a way that is *sensitive*, neither omitting nor distorting beliefs; *practical*, in terms of the resources needed for analysis; *reducible* to summary statistics; *reliable* across investigators; *comparable* across studies; and *informative* regarding the design of communications. To fulfill these requirements, we applied a coding scheme comprised of the expert influence diagram supplemented by the erroneous, peripheral, and background beliefs emerging in the interviews. Using relatively heterogeneous opportunity samples, we found that the number of different concepts elicited by this procedure approaches its asymptotic limit after about a dozen interviews. Figure 2 illustrates this result for two different risks: "radon in homes" and "space launch of nuclear energy sources" (*26*).

Results. Most subjects knew that [...] mentioned), is detectable with a test kit (96%), is a gas (88%), and comes from underground (83%). Most knew that radon causes cancer (63%). However, many also believed erroneously that radon affects plants (58%), contaminates blood (38%), and causes breast cancer (29%). Only two subjects (8%) mentioned that radon decays. During the interviews, subjects mentioned, on average, less than one (0.67) misconception out of 14 concepts mentioned. During the photograph-sorting sessions, they produced, on average, 2.5 misconceptions out of 15 concepts.

Discussion. Respondents expressed many accurate beliefs regarding radon, a hazard for which they may have received little direct education. Unfortunately, some of the misconceptions that did emerge could undermine the value of their correct beliefs. In particular, believing that radon is a permanent contaminant—like other radioactive hazards in the news—could make it seem like an insoluble problem, at least for those who cannot afford extensive remodeling. For instance, we encountered one respondent who had been persuaded by a contractor to replace all the rugs, paint, and wallpaper in her home.

In related research on perceptions [...] (*27*) have found confusion between stratospheric ozone depletion and the greenhouse effect. In fact, some of our U.S. interviewees suggested that giving up hairspray (which no longer contains chlorofluorocarbon [CFC] propellant) will slow global warming. Potentially more serious was many respondents' failure to mention any link between the greenhouse effect and energy consumption.

Structured procedures

Design. Open-ended interviews are essential for allowing the structure of people's mental models to emerge and, in particular, for identifying the set of possible misconceptions. However, the labor intensity of our interview procedure makes it difficult to use for estimating the frequency of each belief in a general population. As a result, the next step in developing a risk communication is to create a structured questionnaire for estimating the prevalence of different beliefs. Such a questionnaire should address all significant expert and nonexpert concepts, translating abstract technical material into concrete language appropriate for lay respondents. To satisfy that requirement, there is no substitute for iteratively testing successive drafts with sub-

Radon interview protocol

What I'd like to ask you to do is just talk to me about radon: that is, tell me what you know about radon and any risks it poses.

Basic prompts:
Anything else?
Can you tell me more?
Anything else—don't worry about whether it's right, just tell me what comes to mind.
Can you explain why?

Exposure processes
Source of radon
Can you tell me (more) about where radon comes from?
Can you tell me (more) about how radon gets into homes?
You told me that ___ (e.g., radon leaks in through the basement)—can you tell me more about that?
Concentration and movement in home
Can you tell me (more) about the things that determine how much radon there is in a home?
Can you tell me (more) about how radon moves around in a home once it gets in?
Is the level of radon usually the same in all parts of a house?

Uncertainty about exposure
Is radon found in all homes?
Can you tell me (more) about how much variation there is in the amount of radon in different homes?

The protocol continues similarly for the other parts of the problem.

jects similar to the eventual respondents. For example, the test that we developed for radon included 58 statements. Respondents could answer "true," "maybe true," "don't know," "maybe false," or "false."

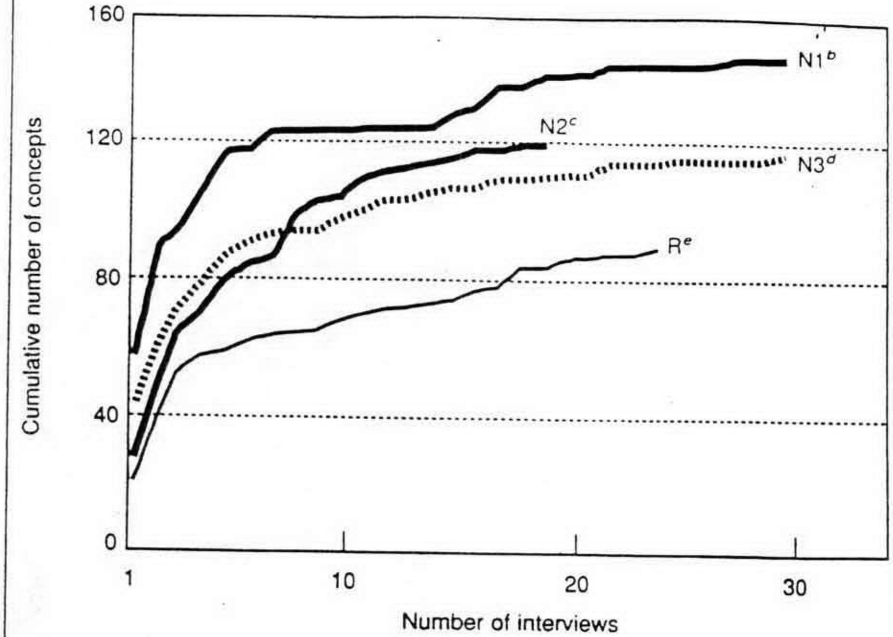
Result. In three small, diverse samples (total $n = 73$), our structured test produced results similar to those from the open-ended interview. For most test items that correspond to single concepts in the expert influence diagram (augmented by nonexpert concepts from the interviews), similar proportions of subjects stated that those propositions were true as had mentioned those concepts in the previous study. For example, 29% of the interviewees and 32% of the questionnaire respondents said that radon can come from water; 21% and 18%, respectively, stated that radon comes from garbage. Thirty-nine percent of questionnaire respondents agreed that "Radon-contaminated surfaces stay contaminated unless they are cleaned or renovated," and only 13% agreed that "radon decays over a few days."

Figure 3 summarizes results from similar studies of lay beliefs about 60-Hz fields (*28*). Results are shown for knowledge of 20 basic concepts drawn from a 54-statement test by three groups of respondents. Each circle represents one concept, characterized by the percentages of right, wrong, and "don't know" responses. The space itself is divided into four regions, representing subjects' typical performance. Consider, for example, Concept 2, the fact that moving charges make currents. Approximately 3% of subjects disagreed with this statement, 73% agreed, and 23% said that they did not know whether it was true. Overall, although there is much confusion, the centers of mass for more than 75% of the concepts lie on the left-hand (correct) side of the plot. The same was true for two other groups of respondents in the study. In this case, in contrast with the radon case, correcting misconceptions would not be as high a priority as building on people's generally correct beliefs about fields.

One weakness of these interview procedures is in revealing beliefs about quantitative relationships. It would be most uncommon for a layperson to say "electric fields fall off with the inverse square of the distance from the source." It is difficult even to formulate structured questions about such topics in lay terms. In other studies, we have used questions involving pictures and diagrams to tap such beliefs (*28, 29*). There, we found that lay respondents could rank the intensity of fields from transmission and distribution lines. However, they did not understand the vast range in the strengths of the fields produced by different appliances. Similarly, their estimates of field strength at different distances from sources suggested an intuitive inverse-power law, but one with a greatly reduced exponent. Given this pattern of results, communications about fields should focus on sharpening beliefs that are correct *qualitatively*, but not quantitatively.

FIGURE 2

Number of concepts as function of number of subjects interviewed[a]



[a] For open-ended mental model interviews on radon in homes and nuclear power in space.
[b] Technology-oriented interview subjects (on nuclear power in space).
[c] General lay public (on nuclear power in space).
[d] Environmentalists (on nuclear power in space).
[e] General lay public (on radon in homes).

Communication materials

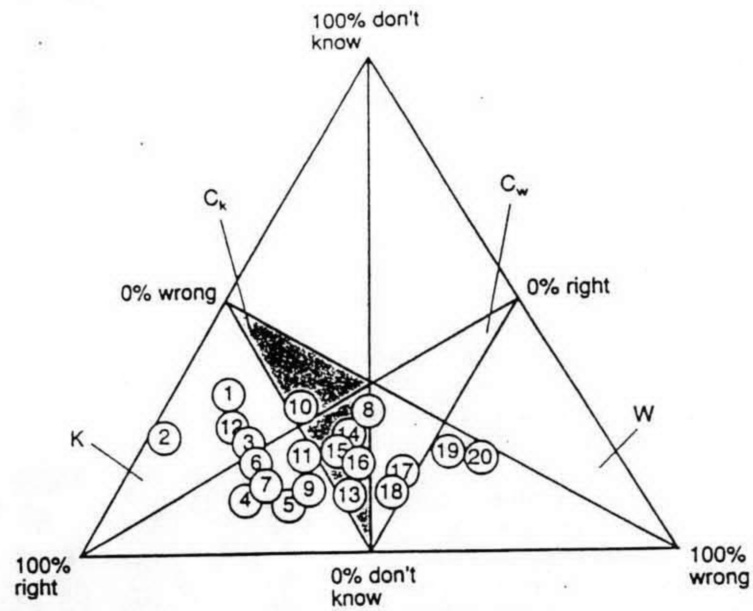
Development. Informative materials such as brochures can attempt to refine mental models in five ways: by adding parts, deleting parts, replacing parts, generalizing parts, and refining parts of people's beliefs (*30, 31*). The need for each of these strategies can be illustrated with findings from our radon interviews.

Important pieces of the basic model of indoor radon exposure and effects processes were often missing from our respondents' mental models (e.g., radon decays quickly, radon causes lung cancer). Adding these high-level concepts might in itself delete or replace erroneous beliefs. Other erroneous beliefs (e.g., radon causes breast cancer), peripheral beliefs (e.g., radon comes from industrial wastes), and indiscriminate beliefs (e.g., radon makes you sick) seem to be derived from mental models of various hazardous processes rather than a core mental model for radon. As a result, they need to be addressed individually.

Based on these results, we designed two brochures. A hierarchical structure for each brochure was derived from a decision-analytic perspective. One (Carnegie Mellon University-DN, or CMU-DN) traced the Directed Network of the influence diagram. The other (CMU-DT) adopted a Decision-Tree framework, stressing the choices that people had to make. Both used higher level organizers that have been found to improve the comprehension and retention of textual material (*32*). These organizers included a table of contents, clear section headings, and a summary. Both brochures contained identical illustrations, a glossary, and a boxed section discussing the assumptions underlying EPA's recommended exposure levels and the attendant risks.

These two brochures were tested against EPA's widely distributed

FIGURE 3
Responses to questions about 60-Hz electromagnetic fields[a]



C_k = Subjects are confused but tend to know the right answer.

K = Subjects consistently know the right answer.

C_w = Subjects are confused and tend to provide the wrong answer.

W = Subjects consistently give the wrong answer.

[a] From random sample of 46 Pittsburgh residents who were asked questions about 20 basic concepts on 60-Hz fields. Circled numbers correspond to concepts.

"Citizens Guide to Radon" (*33*). CMU-DN included all basic exposure concepts in the expert influence diagram and CMU-DT included 89%; EPA included 78%. Each brochure covered 80% of the basic effects concepts. EPA covered a much higher percentage of specific effects concepts (50% versus 13%). The only higher level organizers that EPA used were section headings.

Testing. The three brochures were compared on a battery of measures, including our open-ended interview, our true-false test, a multiple-choice test commissioned by EPA (*34*), a short problem-solving task, and verbal protocols of individuals reading the text. In addition to exploiting the respective strengths of these different procedures, this battery allowed our brochures and EPA's to be evaluated with questionnaires developed by both groups.

In general, subjects reading the two CMU brochures performed similarly, and significantly better, than those reading the EPA brochure (*35, 36*). The greatest superiority of performance was observed with questions requiring inferences on topics not mentioned explicitly in the brochures; these dealt predominantly with detection and mitigation. CMU subjects also gave more detailed recommendations when asked to produce advice for a neighbor with a radon problem. On the other hand, respondents were equally able to recall or recognize material mentioned explicitly in their brochure. Each group performed significantly better than a control group in all respects.

Although subjects of EPA's test did more poorly on the tests derived from the mental models perspective, there was no overall difference in performance on the EPA-commissioned test. Performance on two individual questions deserves note. More subjects who read the EPA brochure knew that health effects from radon were delayed. However, when asked what homeowners could do to reduce high radon levels in their home, 43% of EPA subjects answered "don't know" and 9% answered, "There is no way to fix the problem." This contrasts with the 100% of CMU-DN and 96% of CMU-DT subjects who answered, "Hire a contractor to fix the problem."

Risk communications are complex entities; it is hard to discern which features cause which impacts. We believe that the advantage of the CMU brochures lies in several common features not shared by the EPA brochure: their decision-analytic structure emphasizes action-related information, which facilitates inferences; our preparatory descriptive research focused the content of our brochures on gaps and flaws in recipients' mental models, and principles from research in reading comprehension directed the technical design. One possible additional advantage was that each CMU brochure was written by a single individual, aided by others' critiques. EPA's brochure, on the other hand, was written by a committee consisting of members from diverse backgrounds; perhaps that compromised its coherence.

As a caution, we note that all these results were obtained with relatively small, albeit quite heterogeneous, populations in western Pennsylvania. We anticipate that the prevalence of particular beliefs will vary more across population groups than will the repertoire of thought processes involved in making inferences or absorbing new material.

Conventional wisdom

Although their approaches differed, the projects producing the EPA and CMU brochures both showed a commitment to empirical validation. By contrast, much of the advice about risk communication available in the literature or offered by consultants lacks such commitment. Perhaps the most carefully prepared and widely circulated guidance is a manual for plant managers produced for the Chemical Manufacturers Association (*37*). It focuses on the pitfalls of comparing risks and concludes with 14 paragraph-length illustrations of risk comparisons described with labels ranging from "very acceptable" to "very unacceptable." We asked four diverse groups of subjects to judge these paragraphs on seven scales intended to capture the manual's notion of acceptability (*38*). Using a variety of analytical strategies, we found no correlation between the acceptability judgments predicted by the manual and those produced by our subjects.

One possible reason for the failure of these predictions is that the manual's authors knew too much (from their own previous research) to produce truly unacceptable comparisons. More important than identifying the specific reasons for this failure is the general cautionary message: Because we all have experience in dealing with risks, it is tempting to assume that our intuitions are shared by others. Often they are not. Effective risk communication requires careful empirical research. A poor risk communication can often cause more public health (and economic) damage than the risks that it attempts to describe. One should no more release an untested communication than an untested product (*11*).

Risk professionals often complain that lay people do not know the magnitude of risks (*39, 40*). They point to cases in which people apparently ignore mundane hazards that pose significant chances of injury or death but get upset about exotic hazards that impose a very low chance of death or injury. However, there is counterevidence on both scores.

The earliest studies of technological risk perception demonstrated disagreements in the meaning of "risk" between lay people and experts (and even among different groups of experts) (*41, 42*). As a result, lay people order "risks" differently than do experts. However, if asked to order hazards by their annual fatalities, lay people perform quite credibly (*43–45*). Moreover, differences in the definitions of "risk" reflect political and ethical concerns, such as the respective weights to be given to deaths and injuries to various classes of people (e.g., the young, nonbeneficiaries, those who expressly consent to their exposure). Ignoring these differing definitions poses several perils: neglecting the role of values in defining and managing risks, unfairly deprecating lay people's risk priorities, and failing to provide information on critical dimensions (*46, 47*).

Moreover, even studies that claim to demonstrate inappropriate concerns often use questionable methods. For example, lay people may be asked to rank risks that are hard to compare, and are formulated in unfamiliar terms. We recently asked three generations of subjects (high school students, parents, grandparents) to manufacture their own lists of concerns and then to answer questions about the five risks that most concerned them (*48*). Although our samples were small (n = 87), subjects' self-nominated concerns differed with age to focus on their (self-described) life circumstances.

Lay people often have little opportunity to consider complex risk issues. However, we found that lay opinion leaders dealt well with the risks of the 60-Hz electric and magnetic fields produced by high-voltage power transmission (*49*) when we provided them with the necessary facts and time. Modest analytical assistance probably would have improved their performance further. Poor lay decision making may reflect inadequate time, information, and institutional arrangements, rather than cognitive limitations. When risk communication materials adopt jargon or compressed formats that are not familiar to lay people, understanding can be poor (*50*).

Critics argue that all risk communication is manipulative, designed to sell unsuspecting recipients on the communicator's political agenda. We believe that, with careful design and evaluation, it is possible to develop balanced materials that provide lay audiences with the information they need to make informed decisions about the risks they face. That design must start with an examination of what choices people face, what beliefs they hold, and what expert knowledge exists.

Research on risk communication has just begun. Much "conventional wisdom" withers when subjected to empirical examination. As a result, when developing communications for lay audiences, we see no substitute for the kind of empirical exploration and validation that we proposed in the box, "Four steps for risk communication." This process must be iterative, insofar as even the most careful risk communicators are unlikely to get things right the first few times around. Communicators are not to be trusted in their speculations regarding others' perceptions. The legacy of undisciplined claims is miscommunication, whose price is paid in increased conflict and foregone technological and economic opportunities.

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